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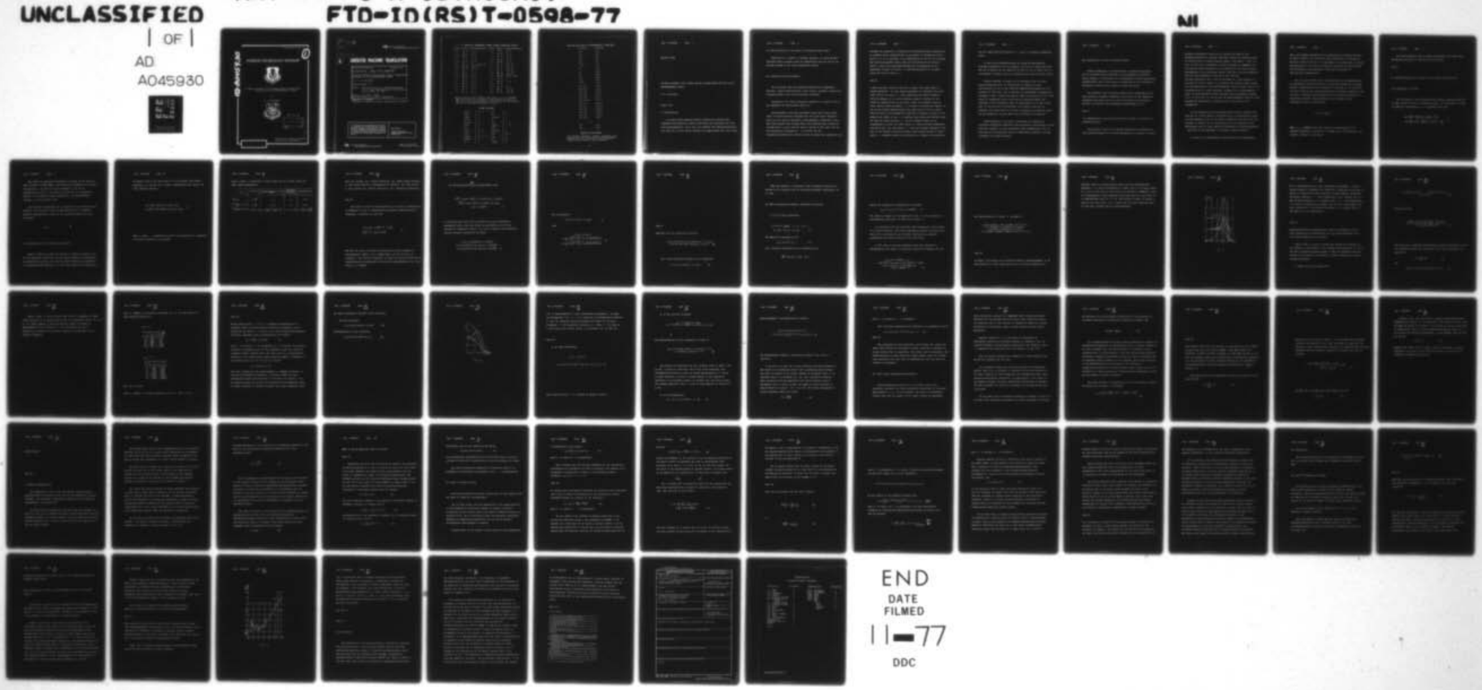

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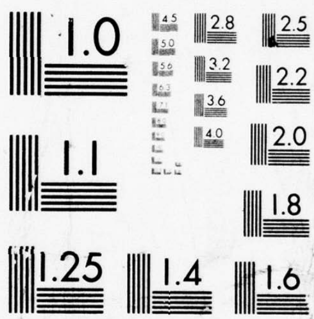

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FOREIGN TECHNOLOGY DIVISION

AT WHICH DISTANCE COULD MARINE ANIMALS COMMUNICATED WITH THE AID OF ELECTROMAGNETIC WAVES

by

G. A. Ostroumov

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By: G. A. Ostroumov

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α α	α	Nu	Ν ν	
Beta	Β β		Xi	Ξ ξ	
Gamma	Γ γ		Omicron	Ο ο	
Delta	Δ δ		Pi	Π π	
Epsilon	Ε ε	ϵ	Rho	Ρ ρ	ϱ
Zeta	Ζ ζ		Sigma	Σ σ	ς
Eta	Η η		Tau	Τ τ	
Theta	Θ θ	ϑ	Upsilon	Τ υ	
Iota	Ι ι		Phi	Φ φ	ϕ
Kappa	Κ ϰ κ	ϰ	Chi	Χ χ	
Lambda	Λ λ		Psi	Ψ ψ	
Mu	Μ μ		Omega	Ω ω	

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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MT/ST-77-0598

AT WHICH DISTANCE COULD MARINE ANIMALS COMMUNICATED WITH THE AID OF ELECTROMAGNETIC WAVES.

G. A. Ostroumov.

Pages 3-24.

I. Introduction.

In recent years appeared several sensational publications, connected with American trader's name Minto and concerning the "new form electromagnetic, until now, not studied" the emission/radiation, with the aid of which marine animals are communicated with each other

at large distances by the means of negligibly small power.

Therefore it is useful to examine question, at which maximum distances marine animals could be communicated with the aid of the already studied by man radio engineering fields.

II. Literature survey/coverage.

If we exclude from the published materials the completely fantastic report/communications, which pursue, probably, advertising target/purposes, then will be obtained following.

Apparently, the first publication appeared on 22 March 1965 in the newspaper of "electronics news" [1].

Correspondent wrote some statements Minto about those waves, which it reveal/detected allegedly for the first time: "hydronic waves are the unusual underwater electromagnetic radiations, which were being spread only through water and connected with electrical oscillations. In this case the word is spread on 250 yards (238 m), and telegraphic transmission - to 30 miles (55 km). Communication/connection affects neither salinity nor temperature nor

pressure nor agitation of surface nor interference from thunderstorm or powerful motor installations. By the means of transmitter with a power 0.1 W it is possible to be communicated at 238 m". In 10 months the same correspondent there gives new interview [2] with Minto, which it said: "was developed antenna for the reception of the underwater signals of fishes .... Emission/radiation is oriented along the axis of dipole ....

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A small hydronic receiver can pick up signal from some forms of fishes (mackerel - of this common mackerels) at distances into 1000 yards (914 m) and more .... This completely new vector radiation field of energy. It it is not possible simply to explain by the fields of conductivity, by the radio waves, the acoustic waves or other earlier known phenomena .... We began to understand fishes". In one of the report/communications this same period [3] it is said: "the new form of electromagnetic radiation is spread in water in the manner that radios in air .... Hydronic waves Minto are emitted along the axis of dipole antenna .... Air for hydronic waves so we nonpenetrate as water for radio waves .... Were utilized frequencies from less than 1 Hz (and above) .... The best antenna consists of the pair of the mutually parallel plates, which radiate normal to their plane .... Hydronic waves are utilized by all fishes for orientation

and for communication/connection .... Minto it organized commercial firm".

In many report/communications are repeated approximately previous information [4]. For example, in [5] it is noted that with the aid of antenna by the length of 50 feet (15 m) at power 10 W it is possible to betray voice up to distance more than 300 foot (90 m).

Without dwelling in detail on the fantastic part of these report/communications, it suffices for an example to note confirmation [5], as if was observed communication/connection at a distance of 1500 feet (430 m) between two apparatuses (transmitting frequency 7 MHz), lowered in water at depth to 250 feet (71 m) at the power of transmitter 250 W, the force of receiving signal not depending on the submersion depth of apparatuses. It is well known that if the test was run correctly, this result could not be obtained. The radio waves of so high a frequency and moderate power can be accepted in the sea water not of further a few meters.

Unfortunately, in the Soviet literature are encountered erroneous estimations supposedly high scientific significance and the practical prospect of this underwater radio communication [6]. In this case to the fantastic parts of advertising character is given sometimes the primary meaning.

III. Description of radio engineering model.

Without submerging in insufficiently illuminated biological parts of excitation and reception of electromagnetic signals by marine animals, I investigate the electrodynamic (radio engineering) possibilities, which could serve as basis/base for the exchange of information between these animals at large distances.

The geometric form of marine animal can be approximated with high accuracy by general ellipsoid. In the case of the imperative necessity this model can be it will be utilized in the future; however, it requires very cumbersome calculations [7, 8].

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For simplification we will be restricted to model in the form of prolate spheroid.

The electric field of the charged ellipsoid of revolution is well studied already in the extent/elongation of century. It served

Abraham as successful basis for the analytical study of the emission/radiation of adjusted half-wave dipole [9]. Maximum length of the body even of largest marine animal - blue whale - only 33 m [10]. In the case of resonance in water (dielectric constant $\varepsilon=81$) this length would correspond to the frequency of the basic natural oscillations of this whip-type aerial 0.505 MHz. The electromagnetic waves of this frequency in sea water with specific resistor/resistance into 4 Ω•m are absorbed in e once already at a distance 0.3 m [11]. Hence it is evident that marine animals cannot use the advantages of the electromagnetic tuning of their body for an interconnection at large distances. Inasmuch as the superstandard range of electromagnetic waves increases with a frequency division [11], the only path to use by them the electromagnetic field of radio engineering frequencies is directed only to the side of low frequencies.

At low frequencies the size/dimensions of marine animals will turn out to be very small in comparison with the appropriate length of electromagnetic wave in sea water. Therefore their body had been generate or receive in the event/reports of the exchange of the information only of field virtually stationary (as time-independent) - this will be the phenomena of virtually "direct current".

In view of the insufficient distinctness of our information

about the possible mechanism of the generation of electric currents by marine animals, and also about their sensitivity to extraneous electric fields, thus far it is necessary to be restricted to further simplification in the model of animal as generator and the receiver of low-frequency electromagnetic field for the purpose of long-distance communication.

Let us bring together this idealized model to equipment/device of experimental Hertz oscillator: two metallic spheres of the small radius r_1 whose centers are arranged at a distance h, are connected with each other by the isolated/insulated rectilinear conducting rod, in which is included point generator or the receiver-indicator of alternating current. The condition of the validity of this idealization are the inequalities

$$r_1 \ll h \ll \lambda_{\text{в}} = \frac{\lambda_0}{\sqrt{\varepsilon\mu}} \approx \frac{\lambda_0}{9}.$$

Here $\lambda_{\text{в}}$, λ_0, ε, μ respectively they indicate the wavelength of the assigned frequency in water and in vacuum (air), the dielectric and magnetic constant of sea water.

For large distances and low signal frequencies this model very corresponds precisely to theoretical pcint dipcle.

Page 6.

IV. Emission/radiation of dipole in the conducting dielectric.

§1. Propagation in vacuum.

By the equation, which describes the harmonic emission/radiation of model dipole (h ≪ R) in boundless vacuum, it is possible to attach in spherical coordinates R, α, θ following form [12]:

$$i\omega E_R = \frac{Ih}{R^3}\left(1 + \frac{i\omega R}{c_0}\right)\cdot 2\cos\theta\cdot\exp\left[i\omega\left(t - \frac{R}{c_0}\right)\right],$$
$$i\omega E_\theta = \frac{Ih}{R^3}\left[1 + \frac{i\omega R}{c_0} + \left(\frac{i\omega R}{c_0}\right)^2\right]\cdot\sin\theta\cdot\exp\left[i\omega\left(t - \frac{R}{c_0}\right)\right]. \qquad (1)$$

The origin of spherical coordinates is placed to the center of model dipole. E_R, E_θ are radial, and meridional components of electric intensities, I - current on input terminals in the rod of transmitting dipole, h - the length of this rod is a shoulder of dipole, ω is an angular signal frequency, c_0 is electrodynamic constant, t is the current time.

The totality of equations (1) is accurate at any finite real or composite (in accordance with the application/use of a symbolic method of designations) values of the quantities during the only limitation:

$$\omega h/c_0 \ll 1. \qquad (2)$$

§2. Propagation in the conducting dielectric.

Table 1 shows the values (in vacuum, in perfect dielectric and in the conducting dielectric) of the current density of displacement and conduction currents, and also the phase velocity of propagation of disturbance/perturbations c, of the group velocity of propagation

of energy w and of the wave factor k. In accordance with Table 1 equations (1), written for a vacuum, automatically are copied for other media as follows:

$$4\pi j_R = \frac{Ih}{R^3}(1+ikR)\cdot 2\cos\theta\cdot\exp[i(\omega t-kR)],$$
$$4\pi j_\theta = \frac{Ih}{R^3}[1+ikR+(ikR)^2]\cdot\sin\theta\cdot\exp[i(\omega t-kR)]. \tag{3}$$

Here j_R and j_θ - respectively radial and meridional the components of current densities in the medium.

Page 7. Table 1. Comparison of some values for the vacuum, ideal and which leads dielectrics.

Среда (1)	Плотность тока. $\vec{j}$ (2)	Фазовая скорость распространения сигнала c. (3)	Групповая скорость распространения энергии w. (4)	Волновой множитель k, (5)
(6) Вакуум	$\vec{j}=\frac{i\omega\vec{E}}{4\pi}$	$c=c_0$	$w=c_0$	$k=\omega/c_0$
(7) Идеальный диэлектрик	$\vec{j}=\frac{i\omega\varepsilon\vec{E}}{4\pi}$	$c=c_0/\sqrt{\mu\varepsilon}$	$w=c$	$k=\omega/c$
(8) Проводящий диэлектрик	$\vec{j}=\left(\frac{i\omega\varepsilon}{4\pi}+\sigma\right)\vec{E}$	$c=c_0\left\{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{4\pi\sigma}{\omega\varepsilon}\right)^2}+1\right]\right\}^{-1/2}$	$w=2c-\mu\varepsilon c^3/c_0^2$	$k=\frac{\omega}{c_0}\left[\mu\varepsilon\left(1+\frac{4\pi\sigma}{i\omega\varepsilon}\right)\right]^{1/2}$

Key: (1). Medium. (2). Current densities. (3). Phase signal velocity c. (4). Group velocity of propagation of energy v. (5). Wave factor k. (6). Vacuum. (7). Perfect dielectric. (8). Conducting dielectric.

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For field of view and simplification in the form of equations it is expedient to pass to dimensionless variables respectively for a frequency, a distance and the time

$$p = iq = \frac{i\omega\varepsilon}{4\pi\sigma},\ a = \frac{4\pi\sigma R}{c_0}\sqrt{\frac{\mu}{\varepsilon}},\ T = \frac{4\pi\sigma t}{\varepsilon},$$
$$\frac{4\pi\sigma h}{c_0}\sqrt{\frac{\mu}{\varepsilon}} \ll 1,\ ikR = a\sqrt{p+p^2}. \qquad (4)$$

Here for the unit of distance is selected the half thickness of high-frequency (with $\omega \gg 4\pi\sigma/\varepsilon$.) skin-layer, and for the unit of frequency - the critical frequency, by which the current densities of conductivity and displacement are equal on module/modulus; for a sea water $\omega_к = 2\pi \cdot 10^9$ rad/s.

To Uravneniyapridat' (3) this dimensionless form:

$$\frac{4\pi j_R R^2}{I} = \exp(pT)\cdot\frac{h\cdot 2\cos\theta}{R}(1+a\sqrt{p+p^2})\cdot\exp(-a\sqrt{p+p^2}),$$

$$\frac{4\pi j_\theta\cdot R^2}{I} = \exp(pT)\cdot\frac{h\sin\theta}{R}[1+a\sqrt{p+p^2}+a^2(p+p^2)]\times$$

$$\times\exp(-a\sqrt{p+p^2}). \qquad (5)$$

In this form they show that the results of radio engineering experiment differ from the results of experiment on the direct "current of spreading" (with p = 0) only in terms of such composite factors (without considering exp (pT)):

$$y_R = (1+a\sqrt{p+p^2})\cdot\exp(-a\sqrt{p+p^2}),$$

$$y_\theta = [1+a\sqrt{p+p^2}+a^2(p+p^2)]\cdot\exp(-a\sqrt{p+p^2}) =$$

$$= [1+a\sqrt{iq-q^2}+a^2(iq-q^2)]\cdot\exp(-a\sqrt{p+p^2}). \qquad (6)$$

Let us designate

$$iq-q^2=(\alpha+i\beta)^2=\alpha^2-\beta^2+2i\alpha\beta. \tag{7}$$

Then

$$\begin{gathered}\alpha^2-\beta^2=-q^2,\ 2\alpha\beta=q,\\ \alpha=q\sqrt{\frac{1}{2}\left(\sqrt{1+\frac{1}{q^2}}-1\right)}=\sqrt{\frac{q}{2}\left(\sqrt{q^2+1}-q\right)},\\ \beta=q\sqrt{\frac{1}{2}\left(\sqrt{1+\frac{1}{q^2}}+1\right)}=\sqrt{\frac{q}{2}\left(\sqrt{q^2+1}+q\right)}.\end{gathered} \tag{8}$$

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Therefore for the equatorial direction

$$y_\theta=[1+a(\alpha+i\beta)+a^2(\alpha^2-\beta^2+2i\alpha\beta)]\cdot\exp[-a(\alpha+i\beta)]=$$
$$=[1+a\alpha-a^2q^2+ia\beta(1+2a\alpha)]\cdot\exp[-a(\alpha+i\beta)]. \qquad (9)$$

For a polar direction formula (9) is simplified

$$y_R=[1+a(\alpha+i\beta)]\cdot\exp[-a(\alpha+i\beta)]. \qquad (10)$$

Thus the analysis of different radio engineering versions is brought to the analysis only of frequency-dependent expressions (9) or (10).

§3. Radio engineering analysis. Equatorial direction.

1. At the high frequencies

$$\omega \gg \omega_k = 2\pi \cdot 10^9 \text{ rad/s} \quad q \gg 1,\ \alpha \to 1/2,\ \beta \to q,$$

$$y_0 \to a^2 (iq - q^2) \cdot \exp\left(-\frac{a}{2} + iaq\right). \tag{11}$$

The modulus of expression (11)

$$|y_0| \to a^2 q^2 \cdot \exp\left(-\frac{a}{2}\right) \tag{12}$$

has a maximum, determined by the differentiation

$$\frac{\partial |y_0|}{\partial a} = q^2 a \cdot \exp\left(-\frac{a}{2}\right) \cdot \left(2 - \frac{a}{2}\right) = 0,$$

whence the coordinate of maximum and its height

$$a_{max}=4;\ |y_0|_{max}=4^2\cdot q^2\cdot\exp(-2)=2{,}16536\,q^2. \qquad (13)$$

The course of value $|y_0|/q^2$ is depicted on Fig. 1 in the function of nondimensional distance a in the form of curve 1.

In connection with the extremely high frequencies, which figure as in these formulas, this radio engineering approach to problem can turn out to be incorrect and therefore necessary its separate examination from optical point of view (see VIII).

E. The case of critical frequency, when bias currents on module/modulus are equal to conduction currents by formulas (4) and

$$\omega=\omega_\kappa=2\pi\cdot 10^9 \text{ rad/s} \quad q=1,$$

$$\alpha=\sqrt{\tfrac{1}{2}(\sqrt{2}-1)}=0{,}45514,\quad \beta=\sqrt{\tfrac{1}{2}(\sqrt{2}+1)}=1{,}09869,$$

$$y_0=[1+0{,}45514a-a^2+ia(1{,}09869+a)]\times$$
$$\times\exp(-0{,}45514a-i\alpha). \qquad (14)$$

The module/modulus of factor y_0 is equal to

$$|y_0| = [(1+0{,}45514a-a^2)^2+a^2(1{,}09869+a)^2]^{1/2}\cdot e^{-0{,}45514a} = \\ =(1+0{,}207107a^2+a^4+0{,}91028a-2a^2-0{,}91028a^3+ \\ +1{,}207107a^2+2{,}19738a^3+a^4)^{1/2}\cdot e^{-0{,}45514a} = \\ =(1+0{,}91028a-0{,}585786a^2+1{,}28710a^3+2\cdot a^4)^{1/2}\cdot e^{-0{,}45514a}. \quad (15)$$

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In Table 2 are brought the calculated values of module/modulus y_0 at some values of a. This table shows that at critical frequency the

greatest field is arrange/located about the same nondimensional distance a = 4, which corresponds by formula (13) to the large values of q. Let us note that at this value of a distance R composes a total of 2 thicknesses of high-frequency skin-layer and for a sea water it is approximately equal to to 2 cm. The effective height of dipole h must be much less than 2 cm. in order that the used equations would be here used (animals must be microorganisms).

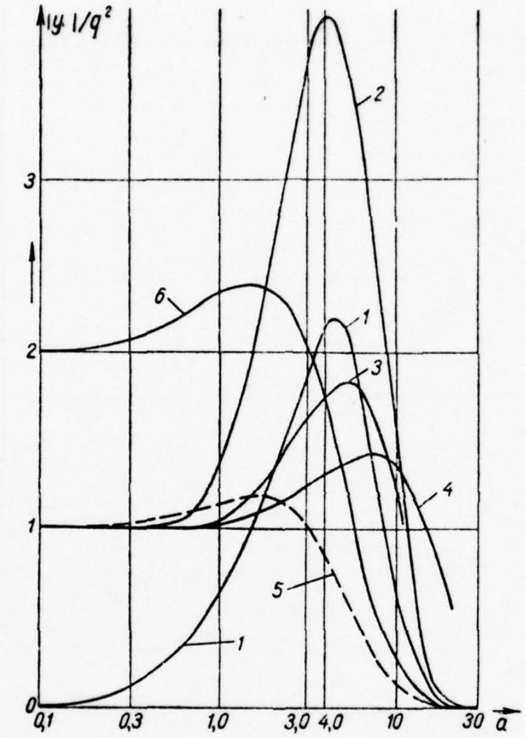

Fig. 1.

Fig. 1. Module/modulus of radio engineering correction $|y|$ to the direct current of spreading as a function of distance. As the unit of length is accepted the half-thickness of high-frequency skin-layer. Equatorial direction: 1 - high frequencies, $q \gg 1$, formula (11); 2 - the critical frequency $q = 1$, formula (15); 3, 4 - low frequencies, $q = 0.3$ and 0.1 respectively, formula (15) and (17) respectively. The polar direction: 5. the critical frequency $q = 1$, formula (26); 6 - the same, but it is multiplied 2.

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Common/general/total considerations about the radiation field of large animals here insufficiently, but for large distances ($R \gg 2$ cm.) these frequencies are useless.

Table 2 (Fig. 1, curve 2) shows that raising the frequency to the critical it contributes to an increase (about value of $a = 4$) in the radio engineering signal almost 4 times in comparison with the signal of the currents of spreading. At large distances the signal strongly decreases.

C. Range of the low frequencies

$$1 \gg 2\alpha^2 = q - q^2 + \frac{1}{2} q^3 + \ldots, \quad 1 \gg 2\beta^2 = q + q^2 + \frac{1}{2} q^3 + \ldots,$$
$$2\beta^2 \to q \to 2\alpha^2 \to 0. \qquad (16)$$

From (9) we find

$$(1 + a\alpha - a^2 \cdot 4\alpha^4)^2 + [a\alpha(1 + 2a\alpha)]^2 \to (1 + a\alpha)^2 +$$
$$+ [a\alpha(1 + 2a\alpha)]^2 = 1 + 2a\alpha + 2(a\alpha)^2 + 4(a\alpha)^3 + 4(a\alpha)^4 =$$
$$= 1 + 2u + 2u^2 + 2u^2(2u + 2u^2). \qquad (17)$$

Here by letter u markedly nondimensional distance, whereupon as unit are accepted thickness of skin-layer at the given frequency [12, pages 413]

$$u = a\alpha = \frac{2\pi R}{c_0} \sqrt{\mu\sigma f}. \qquad (18)$$

Now

$$|y_6| = [1 + 2u + 2u^2 + 2u^2(2u + 2u^2)]^{1/2} \cdot \exp(-u). \qquad (19)$$

Table 3 (Fig. 2, curve 1) gives some values of quantity $|y_0|$. From these materials it is evident that at the low frequencies, when $1 \gg q \to c$, is a small maximum of radio engineering signal, by height of approximately 1.45 at value of u = 3/2. This means that he is observed at a distance 3/2 from the thickness of skin-layer at the assigned frequency.

Table 2. Values $|y|$ at critical frequency ($q = 1$) for some values of nondimensional distance a.

TABLE 2.

a	$\vert y_\theta \vert_{экв}$	$\vert y_R \vert_{поляри}$ (1)
0,5	1,00577	1,0712
1,0	1,3627	1,1570
2,0	2,6318	1,1717
3,0	3,5668	1,0357
4,0	3,9322	0,84563
6,0	3,4209	0,49363
10,0	1,5379	0,12990

TABLE 3.

$u = a\alpha$	$\vert y_\theta \vert$	$\vert y_R \vert$
0,5	1,09345	0,95898
1,0	1,32643	0,82262
1,5	1,45034	0,65054
2,0	1,41294	0,48796
3,0	1,06435	0,24894
4,0	0,66571	0,117281
5,0	0,37278	0,052624
8,0	0,045722	0,0040393
10,0	0,0095472	0,00067492

Key: (1). is polar.

Table 3. Values $|y|$ at low frequencies ($1 \gg q \to 2\alpha^2 \to 0$).

Page 12.

Within limits from u = c to u = 3 frequency characteristic of frequency factor occur/flow/lasts virtually horizontally. If we assume for sea waves σ = 4 $om^{-1}m^{-1}$ [11], then frequency-advantageous conditions (maximum) will be determined by the formula

$$\frac{1}{T_0} = f = \frac{0,045}{R^2}, \quad T_0 = 22,2 \cdot R^2, \qquad (20)$$

here f - in hertzes, R - in kilometers, T_0 - in seconds. The correct selection of frequency here is very important, since the excess of frequency against dcubled value (20) will bring to a catastrophical decrease in the dimensicnless radio-frequency factor $|y_0|$. Actually, at very large values of u $\gg$ 1 it will be obtained

$$|y_0| \to 2u^2 \cdot \exp(-u). \quad (21)$$

With high frequencies the module/modulus $|y_0|$ steeply decreases, so that the low-frequency compcnents of serrated signal the more considerable exceed high-frequency, the greater the distance a (or R). Marine animals can utilize the received by them frequency course of signal strength to evaluate distances frcm their underwater radio

§4. Radio engineering analysis. Polar direction.

For this direction

$$y_R = (1 + a\alpha + ia\beta)\cdot\exp[-a(\alpha + i\beta)]. \quad (22)$$

Module/modulus of this expression

$$|y_R| = [(1 + a\alpha)^2 + a^2\beta^2]^{1/2}\cdot\exp(-a\alpha). \quad (23)$$

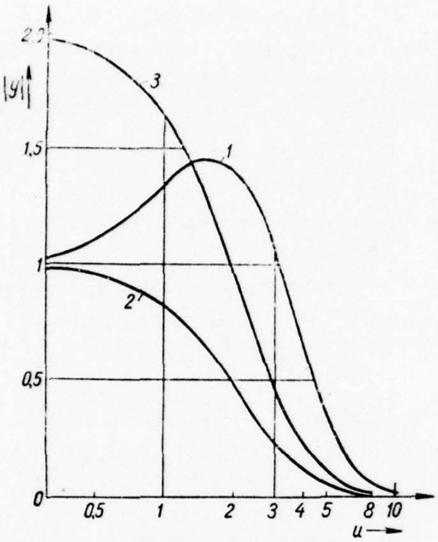

Fig. 2.

Fig. 2. Module/modulus of radio engineering correction $|y|$ at very low frequencies $1 \gg q \to 0$ as a function of nondimensional distance $u = a\alpha$, the expressed through thickness skin-layer at the given frequency: 1 - the equatorial direction; 2 - polar; 3 - the same as 2, but taking into account factor 2 in formulas (1), (3) and (5).

Page 13.

A. At high frequencies.

$$q \gg 1, \ \alpha \to \frac{1}{2}, \ \beta \to q,$$

$$|y_R| \to \left(1 + a + \frac{a^2}{2} + a^2 q^2\right)^{1/2} \cdot \exp\left(-\frac{a}{2}\right) \to aq \cdot \exp\left(-\frac{a}{2}\right). \quad (24)$$

This value has with a = 2 a maximum as height 0.73576 q.

B. At the critical frequency

$$q=1,\ \alpha=0{,}45514,\ \beta=1{,}09869,$$
$$y_R=(1+0{,}45514a+i\cdot 1{,}09869a)\cdot\exp(-0{,}45514a+ia\beta).\quad (25)$$

The module/modulus of this expression is equal to

$$|y_R|=(1+0{,}91028a+0{,}207107a^2+1{,}207107a^2)^{1/2}\cdot e^{-0{,}45514a}=$$
$$=(1+0{,}91028a+1{,}414214a^2)^{1/2}\cdot e^{-0{,}45514a}.\quad (26)$$

The results of calculation by this formula, given in Table 2 and in Fig. 1 (curve 5), show that only at the close distances, when nondimensional distance a does not exceed approximately 0.7, signal in polar direction a little it exceeds signal in the equatorial direction. If we consider factor 2 in formula (5), then polar signal will exceed equatorial (Fig. 1, curve 6) approximately to values of a ≈ 1.8.

C. At low frequencies.

$$q\ll 1,\ y_R=(1+a\alpha+ia\beta)\cdot\exp(-a\alpha-ia\beta).\quad (27)$$

Square modulus $|y_R|$ is calculated as follows:

$$|y_R|^2=(1+2a\alpha+a^2\alpha^2+a^2\beta^2)\cdot e^{-2a\alpha}=$$
$$=\left(1+u+\frac{1}{2}u^2\cdot\frac{1-2\alpha^2}{1-4\alpha^2}\right)\cdot e^{-2a\alpha}\approx\left(1+u+\frac{1}{2}u^2\right)e^{-2a\alpha}. \quad (28)$$

The corresponding values $|y_R|$ are given in Table 4 and in Fig. 2 (curve 2).

It proves to be that for a polar direction the high frequency of the signal of no advantages gives: radic engineering signal always less than the signal of the direct current of spreading. True, if we consider factor 2 in formulas (1), (3), (5), profitably differing polar direction from the equatorial with direct current, then is noticeable (Fig. 2, curve 3) that the signal in polar direction is spread further at values $0 < u \leqslant 1.35$. This value corresponds to signal frequency within the limits

$$0<f<\frac{0{,}0405}{R^2}, \quad (29)$$

here f - in hertzes, R - in kilometers.

With very high frequencies and distances it is possible to write

$$|y_R| \to \sqrt{2}\cdot u\cdot \exp(-u) = \sqrt{2}\cdot a\alpha\cdot \exp(-a\alpha). \quad (30)$$

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The comparison of this expression with formula (21) shows that under these conditions the signal in polar direction is absorbed in larger measure than in equatorial. This means that the observers, who reveal/detected in polar direction larger signal, could not utilize high frequencies for this form of communication, but they used the currents of spreading.

§5. Final radio engineering observations.

From calculations into §3, 4 it is evident that in the equatorial direction the radio engineering correction for distances approximately 1 < a < 10 is favorable: the signal of alternating current more than the signal of the direct current of spreading.

Radio engineering correction is **positive** ($|y_\theta|>1$) **in the** equatorial direction and is negative ($|y_R|<1$) in polar. Polar direction retains its advantage only in the relation to accepted as basis the current distribution of spreading, which in polar direction twice exceed equatorial.

However, distance a = 4, with which the advantages of alternating current are presented maximum, it composes in all the twofold thickness of high-frequency skin-layer. For example, value a = 4 comprises for fresh water 43 m, for marine 2.15 cm. [11].

For the rational selection of frequency at large distances one should use formulas (20) and (29).

If we examine formula (20) from the viewpoint of information theory, then it it is possible to interpret so that the duration of the time, required for the transmission of informational unit under frequency-advantageous conditions, is proportional to the square of the distance between the being communicated individuals of animals. At close distances the velocity of exchange can be much larger than on distant.

On the other hand, the physical structure of formula is such, as if under these conditions information is spread according to the laws

of diffusion. The corresponding "coefficient of the diffusion of frequency-advantageous information" comprises by formula (20)

$$D = 0{,}045 \quad \mathrm{km^2/s} \tag{31}$$

It is understandable that under these conditions the distance of communication/connection is substantially more, if marine animals do not use an example bat. Bat with probing it is necessary in the considerations of directionality to use the carrying high-frequency ultrasound, modulated conformably to form and facts in amplitude and in frequency. Marine animals, on the contrary, are forced according to the considerations of an increase in the distance of communication/connection to emit directly signal itself, but not to modulate by it some carrying more high-frequency transmission, which will be spread to smaller distances.

The phase velocity of propagation of very low-frequency signals by formula out of Table 1 is obtained

$$c = c_0 \left\{ \frac{\mu\varepsilon}{2} \left[\sqrt{1 + \left(\frac{4\pi\sigma}{\omega\varepsilon}\right)^2} + 1 \right] \right\}^{-\frac{1}{2}} \to c_0 \left(\frac{\omega}{2\pi\mu\sigma}\right)^{\frac{1}{2}} = c_0 \left(\frac{2q}{\mu\varepsilon}\right)^{\frac{1}{2}}. \tag{32}$$

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This formula shows that the velocity of propagation of such signals is much lower than the speed of light c_0 not only because the dielectric constant of water is great ($\varepsilon=81$), but main because as the unit of frequency during the determination of dimensionless quantity q it was necessary to select enormous frequencies by formulas (4). Any really/actually low radio-frequency corresponds to very low values of q.

The group velocity of propagation of energy w, computed by the known formula

$$w=\frac{d\omega}{d\left(\frac{\omega}{c}\right)}\to 2c, \qquad (33)$$

strives on by the datum of Table 1 tc the dcubled value of phase velocity. The duration of the time, necessary in crder that the energy of signal would achieve distance R on dimensionless scale and expressed through different variables by fcrmulas (4), will be cbtained

$$T=\frac{4\pi\sigma t}{\varepsilon}=\frac{4\pi\sigma R}{2\varepsilon c}=\frac{4\pi\sigma R}{2c_0\varepsilon}\sqrt{\frac{2\pi\sigma\mu}{\omega}}=\frac{a}{2}\sqrt{\frac{2\pi\sigma}{\varepsilon\omega}}=\frac{a}{2\sqrt{2q}}=$$
$$=\frac{a}{4}\sqrt{\frac{2}{q}}=\frac{a^2}{4u}=\frac{u}{2q}. \quad (34)$$

Formula (34) in dimensional form assumes the fcrm

$$t=\frac{R}{2c_0}\sqrt{\sigma\mu T_0}. \quad (35)$$

Formulas (34), (35) show that at frequency-advantageous value dimensionless variable u = 3/2 duration of the emission of the signal increases as square of distance a or as period T_0 current variations in transmitting dipole. At the frequency-advantageous value of u = 3/2 by means of exception/elimination μ_0 from formulas (18) and (35) let us find

$$t = \frac{3}{8\pi} \cdot T_0 \approx \frac{T_0}{8}. \quad (36)$$

Formula (36) shows that the signals reach correspondent virtually instantly, if we use as time scale the period of a change of the current in transmitting dipole T_0.

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V. Energy considerations.

The completion of short radio engineering (high-frequency) analysis makes it possible to now turn to the properties of direct currents - the currents of spreading, reflected by the remaining cell/elements of formulas (5).

In right side the significant role they play two factors. The first of hem $h/R \ll 1$ presents the angle, hearth with which from the assigned distance R is visible length h of the transmitting physical dipole (possible that it can be at best close to the length of the body of marine animal).

The second factor (sine θ for a tangential field in the place of reception and 2 cos θ for a radial field) emphasizes the advantages of polar direction. This direction coincides with the length of the body of animal and corresponds to concept "along course" its motion.

The left side of formulas (5), which can be reduced to the form $4\pi R^2 j/I$ it shows that at the single value of the right side of formula (5) the current density j in the medium at the assigned distance R is equal to the current in the transmitting physical dipole, distributed to the area of the sphere of radius R.

As a whole the current density of signal decreases with distance as $1/R^3$. This is worse than in vacuum or in the perfect dielectric, where is realized the rule of the decrease of radio engineering signal 1/R. Therefore it is necessary thoroughly to weigh the energy resource/lifetimes of animals and the possible ways of their most advantageous use. For a larger certainty let us be and further apply radio engineering models, ideas and methods of calculation.

As the model of animal will be useful the mentioned above Hertz doublet - two metallic spheres of radius r_1 whose centers are arranged at a distance h from each other, $r_1 \ll h$. The

resistor/resistance of this dipole can be calculated according to the rules of the calculation of spherical grounding [13]. This calculation gives

$$R_э = \frac{1-\left(\frac{r_1}{h}\right)}{2\pi\sigma r_1}. \qquad (37)$$

Here in numerator is placed minus, but not plus on the strength of that opposite polarity of the spheres of the dissimilar dipole unlike the used in electrical engineering analogous/similar grounded electrodes. In this case and further it is considered, that the diameter of the rod of dipole is so less than the diameter of spheres that the portion/fraction of the surface of each sphere, deducted by the connection of rod, can be disregarded in comparison with its remaining surface.

The power of current in the medium will be defined as $R_э I^2_{max}/2$. In connection with the fact that the matching conditions of resistor/resistances require the equal expenditures of power inside and outside the source of signals, total power during the ideal agreement will be determined from the formula

$$P = R_э I^2_{max}. \qquad (38)$$

Here I_{max} is an amplitude value of current.

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Apparently, the most electrically active animal, that preserved on the earth/ground up to now, is electrical slope [14]. The length of its body reaches 2 m, weight 100 kgf, approximately 1/6 this weight it composes the weight of electrical organ/control. The discharge current of the large and unfatigued/rested slopes reaches 8a with 300 V. The product of these numbers is almost 8•300 ≈ 2.5 kW, and quotient estimates the value of resistor/resistance (necessary to set/assume, matched with the medium)

$$R_э = \frac{300}{8} = 37{,}5\ ом. \tag{39}$$

The hence effective diameter of the spheres of equivalent doublet is estimated according to formula (37) at

$$2r_1 = \frac{1}{\pi\sigma R_э} = \frac{1}{\pi\cdot 5\cdot 37{,}5}\ м = 0{,}17\ см. \tag{40}$$

Correcting term in the numerator of formula (37) is negligibly small in comparison with the unit

$$\frac{r_1}{h} = \frac{0{,}17}{2\cdot 200} \approx 0{,}4\cdot 10^{-4} \ll 1. \tag{41}$$

The surface area of the spheres of the dipcle

$$S = 4\pi r_1^2 = \pi \cdot 0{,}17^2 = 0{,}09\ cm^2 \qquad (42)$$

can be identified approximately with the surface area of the exit sections of electrical organ/control on the body surface of animal.

The radio engineering emissivity of electrical slope it is possible to rate/estimate the maximum in 8•2 = 16 meteramperes.

VI. Level of thermal noises.

The energy potential of marine animals must be now compared with the level of potential interferences.

Let us allow first, that the sensitivity of the organ/controls of the reception of electrical signals in animals is limited exclusively by the noises, which cccur from the thermal agitation of electrons [15]. Such a calculation gives the maximally conceivable distance of communication/connection (in the way of applying low-frequency electromagnetic signals).

Average power of the current of such noises at room temperature

is determined by the formula

$$P_{ш} = \frac{10^{-15}}{64} \cdot \Delta f = 1{,}56 \cdot 10^{-17} \cdot \Delta f, \qquad (43)$$

here P - in watts Δf - in kilohertzes.

Let us assume that the receiver bandwidth for the satisfactory transmission of information (as this is obtained, for example, for a telegraphic transmission) is equal to the maximally adopted frequency, i.e., Δf = f - 0 = f.

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We utilize most advantageous frequency by formula for low frequencies (20). Then we obtain the estimation of the intensity of noises, expressed through the distance of the reception:

$$P_{ш} = 1{,}56 \cdot 10^{-20} \frac{0{,}045}{R^2} = \frac{0{,}07 \cdot 10^{-20}}{R^2}, \qquad (44)$$

here P - in watts, R - in kilometers.

Let the model of the receiver of marine animal will be the dipole with effective height h and resistance of medium R_0 by formula (37). Receiving emf of signal at current density j in the medium with conductivity σ will be jh/σ, and the power of received signal under the matching condition of resistor/resistances will be

obtained

$$P_c=\left(\frac{jh}{\sigma}\right)^2\cdot\frac{1}{4R_э}=\frac{j^2h^2\cdot 2\pi\sigma r_1}{4\sigma^2}=\frac{\pi}{2}\cdot\frac{h^2r_1}{\sigma}\cdot j^2. \tag{45}$$

Within the framework of the accuracy of the calculation according to the direct current of spreading and only in advantageous polar direction (i.e. with u < 2 on Fig. 2) let us find from formula (5) the value of the module/modulus of current density j of useful signal in the medium for the substitution of this value in formula (45)

$$j=\frac{hI}{4\pi R^3}. \tag{46}$$

Let us assume that the effective height of the transmitting and receiving organ/controls of animal are identical. From equations (38), (45) and (46) we will obtain

$$P_c=\frac{1}{3\pi}\cdot\frac{h^2r_1}{\sigma}\cdot\left(\frac{hI}{R^3}\right)^2=\frac{h^4}{3\sigma R^6}\cdot\frac{r_1}{R_э}\cdot I^2R_э=$$
$$=\frac{h^4}{3\sigma R^6}\cdot 2\sigma r_1^2\cdot P=\left(\frac{r_1h_2}{4R^3}\right)^2P. \tag{47}$$

From this formula it is evident that the power of receiving signal with the currents of spreading does not depend on the conductivity of

the medium σ and is proportional to the power of transmitter P, but the proportionality factor wholly is determined by the geometry of the construction of model dipole on the scales of the relative distance of the correspondents R.

Let us assume further that the sense organs for electrical signals in marine animals are so ideal which for the reception of information is sufficient in order that the power of signal only would reach the intensity of the noises: $P_c = P_{ш}$.

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This will by formulas (44) and (47) indicate

$$\frac{0{,}07 \cdot 10^{-20}}{R^2} = \left(\frac{r_1 h}{4R^2}\right)^2 \cdot \frac{P}{R^2}, \qquad (48)$$

or

$$\left(\frac{4R^2}{r_1 h^2}\right)^2 = \frac{P}{0{,}07 \cdot 10^{-20}}. \qquad (49)$$

Here R - in kilometers, P - in watts. Utilizing the mentioned example of electrical slope [14] with the parameters

$$r_1 = 0{,}17\ \text{см} = 0{,}17\cdot 10^{-5}\ \text{км},\ h = 2\text{м} = 2\cdot 10^{-3}\ \text{км},\ P = 2{,}5\cdot 10^{3}\ \text{W}$$

we will obtain as the maximally optimum case:

$$R^4 = \frac{(r_1\cdot h^2)^2 P}{1{,}1\cdot 10^{-20}} = \frac{(0{,}17\cdot 10^{-5}\cdot 4\cdot 10^{-6})^2\, 2{,}5\cdot 10^3}{1{,}1\cdot 10^{-20}} = 10,\quad R = 1{,}8\ \text{км}. \qquad (50)$$

Here P - in watts, R, h - in kilometers. The most advantageous frequency of informational momentum/impulse/pulses by formula (19) will be obtained

$$f = \frac{0{,}045}{R^2} = \frac{0{,}045}{3{,}2} = 1{,}4\cdot 10^{-2} = \frac{1}{1{,}2}\ \text{by min}. \qquad (51)$$

Here f - in hertzes, R - in kilometers.

Scarcely whether so slow an information flow could be useful to our model animal. On the contrary, the currents of electrical slope have a character of short-term momentum/impulse/pulses. After assuming that the frequency of these momentum/impulse/pulses corresponds to 1 Hz, we will obtain frequency-advantageous distance from formula (20)

$$R=\sqrt{0{,}045}=0{,}2\ \text{км}. \qquad (52)$$

At this distance, which 9 times than less indicated in (50), the power of reception by formula (47) will be obtained $5 \cdot 10^5$ times more than the intensity of thermal noises according to the calculation conducted. Signal to 6 orders the more powerful, than level of thermal noises, is presented by very probable for providing reliable communication/connection between animals.

On the other hand, if animal really/actually can secrete against the background of thermal noises the signal, equal to them according to power, then at this distance for communication/connection between animal is sufficient the power not 2.5 kW, which arrange/locates electrical slope, but the power to 6 orders less, i.e., $5 \cdot 10^{-3}$ W.

Probably almost all forms of marine animals with surplus are provided for with this power even in the absence of the large anatomicalally designed electrical organ/controls.

These calculations were carried out on the assumption that the only thermal noises can limit the possibilities of radio communication, but other interferences of role they do not play. It is necessary to discuss the usefulness of this assumption.

The highly developed human organism in the process of evolution obtained the very ideal sense organs. For example, the threshold of audibility only on of partial order exceeds the level of the molecular noises of air. Eye distinguishes the flows of world/light, which contain in all only half dozen of photons. True, these data concern the optimum conditions, when organ/controls are managed respectively to silence and to darkness. Nevertheless they show the high degree of the physical adaptability of human organism.

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It is necessary to expect that the marine animals, the duration of existence of which on many orders exceeds the duration of the existence of humanity, are adapted to the medium of its inhabiting not worse than the man. Therefore judgment about the possibility of

the exchange of the information at the level, permissible by the physical spontaneity, is not presented excessively overstated.

On the contrary, from subjective human practice is known also the additional, psychological adaptability, realized by stress of attention. Under conditions of fuss and populousness, we frequently correctly understand by no means distinct telephone conversation, if it concerns vital questions. Analogous adaptability usually is exhibited under conditions of watch or boundary service. As the radio engineering analog of this additional adaptability can serve the correlation methods of reception. It is useful to recall that in all cases of applying correlation methods is necessary to assign supplementary time for the interpretation of correlation.

Inasmuch as the orientation among plunderers and the exchange of the information about the presence of food are for marine animals vital matter, inasmuch as it is possible to assume that the level of thermal noises serves as sufficiently authoritative standard. To it it is useful to rest for the preliminary estimation of the possibility of application/use by marine animals of electromagnetic fields. Those forms of animals, which missed this possibility without the replacement of it by the accelerated multiplication, the increased chemical sensitivity or the organ/controls of protection and attack, were doomed for extinction and at present scarcely they

are encountered.

The intensive attention to this question of biological circles can in the near future replace such estimations with more precise data.

VII. Role of dielectric coatings.

One should discuss the radio engineering possibilities of the dipole whose spheres are covered with the layer of perfect dielectric. This need escape/ensues from the fact that marine animals are deprived of the metallic coatings, which could imitate the surface of the metallic spheres of model radio engineering dipole.

Let the thickness of this layer will be $0 < \delta < r_1$, and dielectric constant will be ε^*.

Then the spheres of model physical dipole are spherical condenser/capacitors (with an outside radius of r_1). The capacitance/capacity of each of them will rate/estimate itself so [12, page 50]:

$$C=\frac{\varepsilon^*}{\frac{1}{r_1-\delta}-\frac{1}{r_1}}=\frac{\varepsilon^* r_1(r_1-\delta)}{\delta}=\varepsilon^* r_1\left(\frac{r_1}{\delta}-1\right). \qquad (53)$$

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Therefore current generator in transmitting dipole must overcome not only effective resistance $R_0={}^1/_2\pi\sigma r_1$ by formula (37), but also capacitive

$$X=\frac{1}{i\omega\frac{C}{2}}=\frac{2}{i\omega\varepsilon^* r_1\left[\left(\frac{r_1}{\delta}\right)-1\right]}. \qquad (54)$$

For this emf of generator it must be respectively increased without a change in the active power. For very thick, of a small dielectric constant and layer a required increase in the stress can at low frequencies be obtained enormously. The corresponding agreement must be realized, also, in the organism of animal, that accepts information. Any changes of the field in the environment this

dielectric coating do not cause, and all the remaining brought out formulas remain valid.

VIII. Propagation in water of electromagnetic waves of infrared region.

In section 4 (§3 and 4) it was shown that the radio engineering evaluation of the range at frequencies higher than critical $\omega_K=2\pi\cdot 10^9$ rad/s, λ_0 = 30 cm. was unreliable. Therefore it is necessary to turn to the results of investigations in infrared region.

Figure 3 on log-log scale depicts the published in the literature results, which relate to the distilled water. Along the axis of abscissas are deposit/postponed the wavelengths of the corresponding oscillations in vacuum λ_0 within limits almost from visible light (λ_0 = 1 μ) to wavelength λ_0 = 1 m. Along the axis of ordinates is deposit/postponed distance x_0, for extent/elongation of which the energy current density (intensity of world/light, umov - Poyting's vector) decreases due to absorption in e once within limits from 1 μ to 0,1 km. (Strength of field E or H decreases in e once at the doubled distance). On the graph/diagram it is represented of 6 dependences of these distances from wavelength λ_0 [16-19].

Figure 3 shows that in the distilled water the absorption of all waves in the indicated range sufficiently is well studied by many researchers by different methods independently of each other; absorption very greatly and cannot allow animals to extract information from sufficiently large distances (for example, more than 1 m) by electromagnetic methods in this wavelength range.

In sea water are suspendn the numerous light-diffusing particles, including animals of different size/dimensions.

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Such particles scatter part of the initial coherent beam of light, than attenuate/weaken its intensity, i.e., is caused absorption. This absorption is difficult to consider in infrared region; however, scarcely whether it less than in visible light. Therefore the data of Fig. 3 one should consider as unattainable optimum.

Thus, and in infrared radiation band of electromagnetic nature cannot be used by animals at large distances.

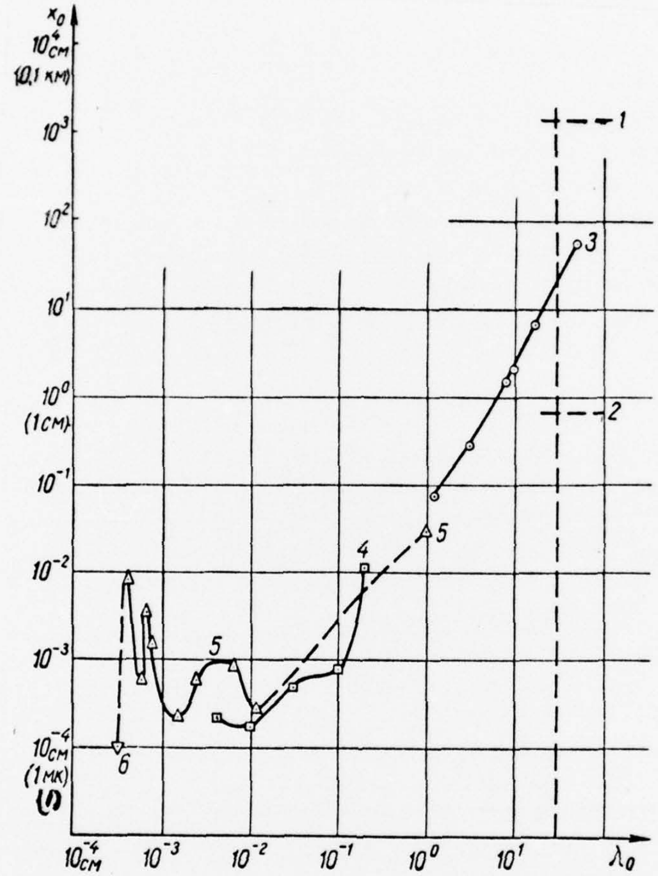
x_0
10^4_{CM} (0,1 KM)
10^3
10^2
10^1
10^0 (1 CM)
10^{-1}
10^{-2}
10^{-3}
10^{-4}_{CM} (1 MK)
1
2
3
4
5
5
6
10^{-4}_{CM}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
λ_0

Fig. 3.

Fig. 3. Literature data on infrared absorption in the distilled water. Along the axis of abscissas - wavelength in vacuum (in centimeters), that correspond to signal frequencies. Along the axis of ordinates - the distances, for extent/elongation of which is observed the energy absorption in e once. Scale is log-log: 1. , 2. [11]; 3 - [16]; 4 - [17]; 5 - [18]; 6 - [19]. The wavelength, which corresponds to critical frequency in sea water q = 1, is noted by vertical dotted line.

Key: (1). μ.

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IX. Conclusion.

The comparison of the radio engineering calculations presented with literature data of the positive content, which do not bear advertising character, noted in literature survey/coverage, shows that the Minto and its followers make mistakes, assigning the observed cases to some "new vectorial fields" [2]. They are right in the fact that used by them for purposes of communication/connection

the electromagnetic phenomenon - the "currents of spreading" - really/actually was thus far little illuminated in the literature on the questions of communication/connection. The currents of spreading greater than were studied in the theory of grounding [13] and in the theory of contacts [20].

The presence of communication/connection on the currents of spreading is evident from the fact that the emission/radiation "is oriented along the axis of dipole" [2]. This occurs precisely because the currents of spreading at close distance and low frequencies by formulas (5) are twice as more as in polar direction, rather than in equatorial. Increasing the size/dimensions of the parallel metallic plates of antenna [3], the inventors they decrease the resistor/resistance of antenna dipole $R_э$ and at the assigned power of transmitter P increase current in dipole by formula (38), in consequence of which the distance of communication/connection it increases. It is understandable that the same result is obtained with an increase in the length of antenna. Minto and its followers correctly note that the intensity of reception does not depend neither on salinity nor on temperature nor on pressure, i.e., on changes in the conductivity of sea water (formula (47)), or on agitation at sea - the wavelength of emission/radiation considerably more the length of sea waves - and on man-made interferences - it is utilized the very low-frequency region of the spectrum. The absence

of interferences due to thunderstorms [1] causes doubt. Velocity of propagation they erroneously exaggerate, although formula (36) can explain their fallacy. It is understandable that the correct experimental setup on biological directionality on the study of electromagnetic radiations by marine animals will give very much useful material both in the plan/layout biological and in plan/layout trade.

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A205	DMATC	1
A210	DMAAC	2
B344	DIA/RDS-3C	8
C043	USAMIIA	1
C509	BALLISTIC RES LABS	1
C510	AIR MOBILITY R&D LAB/FIO	1
C513	PICATINNY ARSENAL	1
C535	AVIATION SYS COMD	1
C557	USAIIC	1
C591	FSTC	5
C619	MIA REDSTONE	1
D008	NISC	1
H300	USAICE (USAREUR)	1
P005	ERDA	1
P055	CIA/CRS/ADD/SD	1
NAVORDSTA (50L)		1
NAVWPNSCEN (Code 121)		1
NASA/KSI		1
AFIT/LD		1

ORGANIZATION		MICROFICHE
E053	AF/INAKA	1
E017	AF/RDXTR-W	1
E404	AEDC	1
E408	AFWL	1
E410	ADTC	1
E413	ESD	2
	FTD	
	CCN	1
	ETID	3
	NIA/PHS	1
	NICD	5